enced men. As concerns pensions, one that does not become assured until the end of a thirty-year period of service, while a great boon to those who finally receive it and a welcome aid to the president in unloading undesired or superannuated professors, nevertheless fails to furnish that assurance of security in case of disability or later financial difficulties which encourages the professor to satisfactorily equip his library, to travel, to study and to surround himself by the broadening influences which are essential to his greatest intellectual development and to his greatest usefulness to the students who come under his instruction. In this matter of pensions and conditions surrounding them we have a valuable lesson to learn from Germany.

It has been argued by some that the early assurance of a pension robs the prospective recipient of initiative and enthusiasm in his chosen profession and encourages a letting up of his intellectual activities. To such as advance this argument the writer begs to enter an emphatic denial of the justness of the accusation, for from his personal acquaintance with professors in many of the leading German universities and his observation of their spirit of research, he is convinced of the utter incorrectness of such a position. Indeed, nowhere in the world could one find greater devotion to duty, greater willingness to make personal sacrifices, or greater zeal in investigation, than among the professors of these German universities, who can look forward complacently to the future if disabled, and in any event with the comfort and knowledge that their families, after their work is done, will be cared for properly as a reward for a lifetime of faithful public service.

Finally, this society will do well to encourage the development in our universities of higher and broader graduate courses in the applied sciences related to agriculture. Let us use our influence as a body to secure from the Carnegie Foundation, for the teacher and investigator in the smaller land-grant colleges, the same fair and just recognition for quality and amount of public service rendered as is accorded to the teacher of mathematics or of the classics in the older classical colleges of the country. If necessary, let the American Society of Agronomy urge upon congress the provision of a pension system for the land-grant college, based upon a reasonable probationary limit of service as a condition for its becoming assured. If to this these colleges will add the sabbatical year, or will allow a full half-year in every five, and will give adequate and progressive advances in salary with the years of service, we shall soon see plenty of young men fitting themselves well for the work of teaching and research.

In closing I would not fail to emphasize that young men entering our profession should do so with the missionary spirit and with the desire to serve their fellows uppermost in mind, but the situation to-day is such that many who set out with courage are forced, out of justice to their families and through failure to secure the reasonable comforts and necessities of life, to seek, against their will, such financial returns in other callings as are rarely the reward of the agricultural teacher and investigator.

H. J. WHEELER

THE INTRODUCTION OF PHYSICAL CHEMICAL CONCEPTIONS IN THE EARLY STAGES OF THE TEACHING OF CHEMISTRY [1]

THE question I have been asked to discuss is not a new one, but is, in my opinion, one of fundamental importance. Whenever any

[1] Paper read before the American Chemical Society in Washington, December 27, 1911.

great advance has been made in any branch of science, the question has arisen how early should this be incorporated in the teaching of that science; in a word, how closely teaching should follow research, and various answers have been given.

That we are dealing here with a fundamental question is obvious after a moment's reflection. Shall we teach the beginner, in a judicious way, of course, the science as it is at the time in question, or shall we teach him what is not only hopelessly out of date, but what is known to be absolutely untrue?

In answering this question we must take into account that the beginner of to-day is the advanced student of to-morrow, and the chemist of the near future. It is true that most of the beginners in any branch of science never pursue that science at any length, and to these perhaps the least harm is done by teaching the science in an out of date manner; but the question becomes more serious when we are dealing with those who propose to devote their lives to the branch of science in question.

Why has the question that we are discussing arisen at this time? As is well known, it has come to the front as the result of certain fundamental discoveries made in chemistry towards the later part of the last century. These are usually known as *physical-chemical generalizations,* because they were reached through the application of physical methods to chemical problems.

I think the term "physical-chemical" is unfortunate, because it may leave the impression that we are dealing here with something different from chemical, while, in fact, we are not. Indeed, I think the term "physical chemistry" is unfortunate, since it may lead to the conclusion that here is something that is not chemistry, while it is simply an integral part of chemistry. I greatly prefer the term "general chemistry" or "generalized chemistry"; since the generalizations which have been reached in this field concern most vitally and fundamentally the whole science of chemistry. This same thought is echoed in the title of Ostwald's great work, "Lehrbuch der allgemeinen Chemie." The term "physical chemistry" is, however, so widely disseminated, and the leading journals in this field in German and French both bear this title, so that the hope of reform in this nomenclature seems remote.

The generalizations that we have in mind are: The discovery of the Law of Mass Action, by the Norwegian physicist, Guldberg, and the Norwegian chemist, his son-in-law, Waage, in 1867; the discovery in 1886 of the applicability of the laws of gas-pressure to the osmotic pressure of dilute solutions of non-electrolytes, by one of the greatest men of science who has ever lived, Van't Hoff; and the explanation by Arrhenius in the same year, of the apparent discrepancies presented by electrolytes, *i. e.,* the announcement of the theory of electrolytic dissociation; of less importance perhaps is the interpretation of chemical valence in terms of Faraday's law, but scarcely so, at least from the pedagogical standpoint; and finally, the discovery of the electron, by Sir J. J. Thomson, and the instability of the chemical atom, by Rutherford.

The question then is, shall these generalizations be taken into account in the early stages of the teaching of chemistry, or shall they not? I know of no productive chemist who doubts the value of introducing them into more advanced stages of work. To do so would be to teach and learn a science of chemistry, with the science all left out.

A fair way to judge of the value of any discovery is to imagine that it had not been made, and see how the science would be affected by its absence. Similarly, in dealing with a question like the one under discussion, it would seem to me that a logical way to approach it would be to ask, What is lost by not incorporating the modern advances into elementary chemistry, and then what is gained by doing so?

It is certainly true that if we omit these generalizations from the early stages of chemical work we are teaching something that is out of date. There can be no two opinions on this point. But this alone does not solve our problem.

Perhaps the science as developed twenty-five years ago is better adapted to teaching the beginner than is the chemistry of to-day. It is certainly simpler. Why not teach the first year student in chemistry, in addition to a judicious number of the empirical facts of the science, something about the atom and the molecule, and leave it for a later stage to present the more recent developments? What would be lost by so doing? We have now arrived at a fundamental question.

The answer to this question is, in my opinion, that we must no longer teach the chemistry of three or four decades ago, because we know that in many fundamental points *it is untrue.* But it might be answered, we grant you this, but for the sake of *simplicity* we will teach the old chemistry, for, say a year, and then turn the student over to the new.

It is right here that an insuperable difficulty is encountered. It is the *persistence of first impressions.* Any one who has observed this at all carefully knows how nearly impossible it is to correct erroneous first impressions. Whatever the physiological or psychological explanation of the persistence of these impressions may be, the fact remains.

I have had this brought home to me so often and in such a forcible manner that it has made a deep and lasting impression. It has been my lot to try to teach something of the newer developments in chemistry to some students who have been trained in the older school. The result has been that it has required years of incessant drilling to ingraft the new generalizations into the mind of such a student. At first, the newer conceptions were scarcely more than tongue deep. In answer to questions it would be stated at first that "it is said" that such and such is true, or "the book says," or "you said" that this or that is the explanation; all of which went to show that the new ideas had penetrated hardly more than skin deep, and this, notwithstanding a serious effort on the part of an honest student to make the real science of chemistry an integral part of himself.

What is the explanation of this rather distressing condition of things? *Erroneous first impressions,* from which it is almost impossible wholly to escape.

There is one other matter to which I should like to refer before leaving this part of the discussion. This is the tendency which has existed in the past in this country to make chemistry *easy.* I do not believe there can be much difference of opinion as to this being a fact. How often and how justly have we heard the elementary course in chemistry branded by the student body as a "snap"; and for this very reason a preponderating number of students elect this course.

This condition is nothing less than *fatal,* as far as the science of chemistry is concerned; and every serious teacher must study its cause and apply the remedy.

How has this condition come about? Largely, I believe, as follows: A quarter of a century ago chemistry was almost wholly an empirical branch of science. Rowland used to say that chemistry in his day was in the same stage of development as physics in the days of Michael Faraday; and this was only a slightly exaggerated statement. It was necessary at that time to present the subject of chemistry largely by the empirical method. The result was with chemistry, as with any other empirical branch of science, the comprehension of the subject involved primarily, and may I say chiefly, the memory. A reasonably developed memory is much more general than equally well developed reasoning powers, and the use of the latter involves the expenditure of far more mental energy than the use of the former. This is the reason why chemistry was regarded as *easy.* It was something that could be readily memorized.

While this was perhaps a more or less necessary condition, several decades ago, those conditions are now largely changed. Chemistry is rapidly advancing along the way to become a branch of exact science, and it can be dealt with to-day in no small measure by the deductive method.

Far be it from my purpose to make chemistry *hard,* or even harder than is necessary for the best good of the science, at least in the early stages of the study of the subject; but a

far more important object than to make chemistry easy is to make it scientific. The object of the teacher should be to make the subject *clear,* but I have not very much respect for making things easy, since in science whatever is *easy* is *superficial.* There is no inherent reason why we should make elementary chemistry appreciably easier for the average student than elementary physics; that is to say, make it more superficial.

The argument against introducing the newer generalizations into the elementary teaching of chemistry, based upon the fact that their omission renders the subject easier, is, then, in reality a strong argument in favor of incorporating them.

The question as to whether it is easier for the teacher to introduce or omit the newer conceptions does not enter into the present discussion, since every efficient teacher is abreast with the development of his science; and furthermore, in matters of teaching, it is only the best good of the student that is to be considered.

Let us now turn to the other question: What is *gained* by teaching elementary chemistry from the standpoint of the newer generalizations?

A beginner in chemistry soon learns that when a chloride is treated with concentrated sulphuric acid, hydrochloric acid gas escapes, and the chloride is transformed into the corresponding sulphate. At one time this was explained as due to the greater *strength* of sulphuric acid; but we can not offer this explanation any longer, since we now know that sulphuric acid is only a little more than half as strong as hydrochloric.

The same beginner quickly learns that when a solution of a chloride is treated with a solution of silver nitrate, insoluble silver chloride is precipitated.

These two classes of phenomena are typical of a large number of chemical reactions. In the past such facts were summarized by saying that whenever a gas can be formed it is formed, and whenever a solid can be formed it is formed. This was simply *renaming* the phenomena in question, but of course explained nothing. Yet it was the best that could be done at that time.

It is a very simple matter to give any one, and therefore a beginner in chemistry, some qualitative conception of the effect of mass or quantity on chemical reactions—chemical reactions being dependent upon two things, the nature of the substances brought together, and their relative quantities. If the beginner can grasp one of these conceptions he can grasp the other.

Given the conception of mass and even qualitatively its function in chemistry, the two typical reactions mentioned above can be interpreted or, indeed, explained.

Hydrocloric acid having a low boiling point is a gas at ordinary temperatures, and escapes from the field of action almost as rapidly as it is formed; its active mass being thus reduced nearly to zero.

The silver chloride formed is nearly insoluble in water. It is precipitated as a solid and its active mass is thus small. I think this treatment renders the two typical reactions more clearly understood, and is more scientific than simply renaming the phenomena.

I venture to predict that not a few students of chemistry, not only of one year's standing but of several, are without any adequate conception of the importance of that condition in which matter in a given state of aggregation is, when mixed with matter in the same or a different state of aggregation—in a word, of the importance of *solution.*

If they were told that the whole science of chemistry is a branch of the science of solutions, they would either not understand the statement at all, or would regard it as a gross exaggeration.

It is a simple matter to make this reasonably clear, at least towards the end of the first year's work in chemistry. By that time enough reactions have been studied to show the student that practically all, if not all chemical reactions take place in solution, using the term solution in the broad sense in which it is employed to-day. Matter in the pure homogeneous condition is scarcely

capable of doing anything chemically, and that the science of solutions is much broader than chemistry will be seen after a moment's reflection. Geology is largely a science of solutions—of aqueous solutions and molten magmas, and how many branches of the biological sciences owe their existence to matter dissolved in other forms of matter?

In the pure homogeneous condition matter is, as we have stated, relatively inert. Nature, and, consequently, the science of nature, is, as it is, primarily due to matter in the dissolved state; and our knowledge of solutions, thanks to Van't Hoff and Arrhenius, is now reasonably satisfactory. We know far more about matter in the gaseous state than in the liquid or solid state. Van't Hoff has shown us that we can deal with solutions in many fundamental respects as we deal with gases. Consequently, we know far more about matter in solution than in the pure homogeneous liquid or solid condition. Why should these facts be concealed from the student of chemistry until late in life?

And now we come to another fundamental matter—the nature of the units that take part in chemical reaction. For a long time it was taught that the atoms and the molecules are the active chemical agents, and this was in keeping with what was known at the time.

This is now largely changed. The number of concordant lines of evidence which show that electrically charged parts are necessary for chemical activity, is so great, that I know of no productive chemist to-day who seriously questions it. After thinking over this problem and working upon it for a good many years, I am of the opinion that there is no chemical reaction known to man in which at least one of the substances taking part in the reaction is not more or less ionized. Indeed, I am unable to form any physical conception of even the posibility of a chemical reaction between electrically neutral parts, any more than I can form a conception of two electrically neutral bodies attracting or repelling one another electrically. It would lead us much too far to discuss at all fully this question here, nor is it necessary to do so. To furnish evidence to-day for the general truth of the theory of electrolytic dissociation, would be as unwise and as useless as to furnish new evidence for the law of the conservation of energy, or for the law of the conservation of mass.

In the light of these facts are we justified in continuing to teach the beginner the old chemistry of atoms and molecules, which we know, or should know, is untrue; trusting to later years, to new experiences, or to another instructor to correct these erroneous first impressions, which, as has been stated, is well nigh impossible.

Take another phase of things. A phenomenon which must be encountered very early in the study of chemistry is *precipitation*, already referred to in another connection. Has it been possible to treat this subject scientifically until quite recently? I think not. Whenever a precipitate could be formed it was formed, was about the way this matter was left. In the chemical reaction in question a solid is formed, which is practically insoluble in the solvent used; and being insoluble it is thrown down in that coarse-grained condition that we call a precipitate.

Think of this for a moment. When the solid was formed it was probably in a state of molecular aggregation. How do these solid molecules know enough to come together and form aggregates of the sizes that exist in precipitates? Furthermore, if this is the "natural condition" of insoluble solids when formed in a chemical reaction, then why do we not *always* have precipitation when an insoluble solid is formed in a reaction? In a word, why do we have in some cases *colloidal suspensions?*

To fix the idea and by way of illustration, why is arsenic sulphide precipitated when arsenic chloride is treated with hydrogen sulphide, but is not precipitated when arsenic oxide of the same concentration as the chloride is treated with hydrogen sulphide? Not only must every teacher of chemistry have asked himself this question, but every intelligent student, before he has advanced very far, must do so.

This is now very satisfactorily explained by another really great man of science—a man whose work for chemistry is quite as fundamental as his work for physics—I refer, of course, to Sir J. J. Thomson.

He has shown that whether or not precipitates are formed is dependent upon the presence or absence of appreciable numbers of charged parts or ions. Arsenic sulphide is precipitated from the solution of the chloride because the hydrocloric acid set free by the action of the hydrogen sulphide is strongly ionized. On the other hand, arsenic sulphide is *not* precipitated from the solution of the oxide, because no strongly dissociated substance is formed as the result of the reaction, and neither arsenic oxide nor hydrogen sulphide is strongly dissociated.

But Thomson does not stop with showing that ions or charged parts are necessary for precipitation. It was shown by Burton, working in Thomson's laboratory, why, or at least how, this is the case. Space will not allow me to go into this in detail. Suffice it to say here that, the colloidally suspended particles are charged electrically, and for any given colloid all of the particles are charged with the same sign. These electrical repulsions work counter to surface-tension, which acts so as to draw the particles into the smallest surface for a given mass—to draw the colloidally suspended particles into lumps as in an ordinary precipitate. When ions are present these electrically neutralize the charges upon the colloidal particles and allow surface-tension to produce its full effect.

That ions are necessary and sufficient to effect precipitation, can readily be shown by adding almost any electrolyte to the colloidally suspended particles of arsenic sulphide, obtained by treating the oxide with hydrogen sulphide. A precipitate is formed at once.

This work places the whole subject of precipitation, for the first time, upon a scientific basis, and while it can not be presented fully to a beginner, I see no reason why it should not be judiciously taught to a student in his second year of chemistry, *i. e.*, when he is studying qualitative and quantitative analysis.

Then arise some of the most fundamental problems. What is a chemical atom? If made up of parts what are these parts, and how are they arranged within the atom? How does one chemical atom differ from another chemical atom? Are the chemical atoms stable?

These matters must all be taught the student of chemistry and the question is when? They can not of course all be presented fully to what we ordinarily mean by a beginner, but I can see no reason why they can not be presented, in an elementary manner of course, at the proper places, even in the first year's work in chemistry, unless we are wedded to the dogma that chemistry must be made *easy* in order that it may be *popular*.

We can certainly no longer teach that the chemical atom is an "ultimate unit" in the light of the recent work of Thomson. We know that it is made up of parts, and furthermore, we have some idea how these parts are arranged in two dimensions in space in a section through the atom. We have very good reason to believe that most, if not all of the differences between the atoms of the various chemical elements are a function of the number, arrangement, and possibly the velocities of the electrons composing the atoms. And why not, in a common-sense manner, tell the student of chemistry so, even in the comparatively early stages of his work?

Indeed, I think it is far simpler to teach this fundamental connection between the elements, than to have the beginner look upon the eighty or more elementary substances as so many discrete, disconnected, and fundamentally unrelated kinds of matter—to say nothing of it being true; and in the teaching of science I think *truth* is even more important than *simplicity*.

And again, take the question of the *stability* of the chemical atom. The stable atom of the past is now hardly more than historically interesting. The work of the Curies and especially of Rutherford, on radioactive sub-

stances, has placed this almost beyond the pale of doubt. The atoms with the largest atomic masses are certainly unstable, and it is highly probable that the atoms of all the elements are undergoing devolutionary changes.

In the light of these facts are we going to persist in teaching the stable atom, without qualification even to the beginner, and rely upon time, fate or the effort of some one else to correct, if possible, the evil that we have done? It is perfectly true that the stable atom is simpler for the beginner than the unstable atom, but here again it is *simplicity vs. truth.*

In conclusion, there is one other matter which I can not leave untouched, because it lies at the very foundation of our science. I submit that no serious student of chemistry, and this is the class for which we must be most concerned, can study the subject for six months, learning that certain things react chemically with certain other things, and that certain things do not react with one another, without asking himself the question, why is this? Why do some substances react, and why do others not react? If this question is not raised by the student it certainly should be by the instructor. The question then is, why do chemical reactions take place at all?

We might almost call this the most fundamental question of chemical science. It is certainly so for the student, and that in the early part of his career. This brings me to the most heterodox position that I have yet ventured to take.

Should we not introduce into our elementary courses in chemistry something about the *energy changes* that take place in all chemical reactions, and which make those reactions possible? In the evolution of chemistry the material changes were studied first, and this was natural. These changes were the most obvious, and the material products were often desired for one purpose or another. Again, these material changes were the easiest to study, and chemists, like other men, were inclined to follow the lines of least resistance. I believe the nineteenth century will go down in the history of chemistry primarily as the period of *material chemistry.*

But even this is changed now. Without decrying in the least the study of matter, the chemist of to-day insists that we can no longer ignore the changes in energy that manifest themselves in every chemical reaction. Indeed, he would even go further, and point out again that whatever is easiest in science is relatively most superficial.

We know to-day that *all* chemical reactions are really due to differences in the intensity, or quantity, or kind of the intrinsic energy present in the substances that are to react; and whether any two substances will or will not react is determined primarily by this difference. We can, furthermore, form a physical conception now of what is meant by intrinsic energy, since we have the electron theory of the atom; it is primarily the kinetic energy of the moving electrons within the atom.

But dare we venture even to refer to energy or energy changes in the early stages of the teaching of chemistry? I ask why not? The physicist does not hesitate to do so. Indeed, most of his subject has to deal very largely with changes in the different manifestations of energy. Why should we assume that the chemical student has less natural intelligence than the student of physics, especially when he is almost always the same student? (In my opinion no one should be allowed to begin the study of chemistry until he has had at least one year of physics.

There is, of course, no reason for assuming that the beginning chemist is not as intelligent as the beginning physicist, and, therefore, there is no more reason why a student of chemistry should not deal with changes in energy than a student in physics, especially when these energy changes are as fundamental for chemical science as they are for physics.

Instead of teaching to-day that chemical reactions are *accompanied* by energy changes, why not teach the truth, which is, that it is these very energy changes that are the cause of all chemical reaction? Systems which alone are fairly stable, when brought together

may become unstable. There is a running down of a part of the intrinsic energy of one or both of the substances into heat, light or electricity but almost always largely into heat; and the substances rearrange themselves into those new combinations which are most stable under the new conditions.

This is what we ordinarily describe as a chemical reaction, and this can be taught to any sensible student just as well as the elements of physics can be taught to him.

Finally, the matters herein referred to, together with many others which time will not permit me even to mention, can not, of course, be taught the beginner all at once, in addition to the so-called material facts of chemistry. It is, however, a fair question to ask whether some of these matters would not be a fair substitute for a part of the pyrotechnics that sometimes adorns the chemical lecture table?

In all such matters the judgment and common sense of the teacher must of course be the final guide, and the intellectual fiber of the student must also be taken into account. It goes without saying that we must not teach dogmatically anything to the student of chemistry, much less to the beginner in chemistry, that is not reasonably substantiated; but I believe that all of the matters referred to above and many more of their type belong in this class.

The final question then is, shall we have two chemistries or one? Shall we have a chemistry of research, pushing forward at a pace that makes the last twenty-five years mark a distinctly new epoch in the history of the science? and another chemistry taught the beginner, which practically ignores all that has been done within that period; which deals not only with what is obsolete, but with what we know to be largely untrue, and which relies upon subsequent teaching to do almost the impossible, *i. e.,* correct erroneous first impressions, which must in some method be corrected, or the result is fatal?

Or shall we have one science of chemistry? Research leading the way, and teaching following fairly closely behind? At least doing nothing that will have to be undone, but incorporating what is truest and best.

For those who believe as I do that the latter is the more scientific course, there is not only no ground for pessimism, but not even for pragmatic meliorism.

The progress in this direction during the last decade, not only in the better colleges and universities, but in the more progressive high schools, has been so rapid that there is room for nothing but the most cheerful optimism.

Harry C. Jones

IS SCIENCE REALLY UNPOPULAR IN HIGH SCHOOLS?

The period covered by the tenth decade of the nineteenth century and the first of the twentieth was one of great activity in the reconstruction of high school schedules. The reports of the N. E. A., Committees of Ten and on college entrance examinations, the formation of the College Entrance Examination Board, the Perry and other movements for the reform and unification of science and mathematical teaching, all must have influenced high school curricula, and the alterations of the curricula must have shown effects in the percentages of secondary students in the various courses.

The famous attack made by President G. Stanley Hall[1] on the methods and attitude of secondary teaching in the United States was based to a certain extent on the summary tables of the percentage of secondary students in the United States taking the various high school studies, and published in the reports of the Commissioner of Education, 1890 to 1907. In order to exhibit these I have plotted the data on a chart. The curves for studies, graduates and college preparatory students are from the summary table (p. 1052), Report of the Commissioner of Education for 1907; that for per cent. of secondary students

[1] G. Stanley Hall, "How Far is the Present High School and Early College Training adapted to the Needs and Nature of Adolescents?" N. E. Asso. Coll. and Prep. Schs., 16, p. 72, 1901; *Ped. Sem.*, 9, p. 92, 1902; *Sch. Rev.*, 9, p. 649, 1901.